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Parking Guidance and Authentication System

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Abstract: There are two important problems related to the management of large parking areas, which are time for searching available lots and detecting unauthorized-parking vehicles. Nowadays, there are parking guidance systems that guide the drivers toward the available lots. As a result, the systems reduce the time for searching available lots. However, these systems do not solve the problem of unauthorized-parking vehicles. This paper presents a combination of parking guidance and authentication system that is capable to verify the legality of vehicles parked at authorized-parking lots. This system consists of detection and identification modules. In the detection module, wireless sensors such as ultrasonic and magnetometers have proven their ability in detecting vehicles. In identification module, nRF24L01 with controlling of data collision, tag address, and reception acknowledgement are used, which will act similar to an active RFID. Such system has significant implications for large institutions, by making the parking lots allocated to their staff available within the same customer parking area. The system will reduce the required manpower for managing parking areas.

Keywords: RFID, parking guidance, parking monitoring, smart tag, vehicle identification.

1. Introduction

Parking lots issue is one of the most important facilities that must be provided by large institutions such as airports, universities, malls, stadiums and hospitals. Nowadays, there is a rapid increase in the number of vehicles. As a result, there is a need to provide more parking spaces than before.

The problems related to the parking areas will not be ended by increasing them. If we increase the number of the parking lots, it will become like a maze in order to find an available lot. This would result in wasting time for searching an available parking lot. As a result, it will cause a traffic jam in that parking area, especially during the peak time. However, these problems can be avoided by using parking guidance systems.

According to Caicedo [1], the problem of wasting time for searching an available parking lot contributed in increasing the pollution of the environment. Therefore, providing drivers the information of available parking lots will dramatically help in solving this problem.

Another problem, which is considered as one of the most obvious problems suffered by institutions that have limited parking area, is the situation of unauthorized-parking. For example, someone parks his/her car at the parking lot designated for the employees of that institution.

Wanger and Straton [2] stated that there were many efforts made to prevent unauthorized-parking problem. The most commonly used workarounds was to prevent the non authorized vehicles from entering the authorized parking area by using a barrier boom or a controlled gate. This can be done either manually (by the parking supervisor), or automatically by magnetic cards or similar means.

Guozhong et al. [3] presented a system for guiding drivers toward the available lots. The system is called "parking guidance and information system - PGIS" and it had two main goals. The first goal was to provide the driver with information about direction to the available lots and the second goal was to provide the management of that parking area with information about the status of all parking lots. Ultrasonic sensors were used to detect the presence of vehicles in each parking lot. This information is gathered by data collectors and used for guiding the drivers toward the available parking lots. The study says that without using the PGIS, the management of the parking area required at least 20 employees, but after using the parking guidance system, it required only 3 to 5 employees. The cost of the PGIS can be recovered within less than two years. In addition, the management of that parking area became easier.

Sangwon et al. [4] investigated the accuracy of many wireless sensors for vehicle detection, such as visual light sensor (PerkinElmer, VTB9412B), infrared sensor (Advanced Photonix, Inc., PDB-C139F), temperature sensor (Maxim Integrated Products, MAX6612MXK), magnetometer sensor (Honeywell, HMC1052), and ultrasonic sensor (Devantech SRF02). They analyzed the reading of all sensors that are tested in a multi-storied university parking area. Data were collected through three experiments: presence detection experiment, vehicle transmission experiment and vehicle counting experiment. The main finding of all experiments is that not all wireless sensors are suitable to detect vehicles, except the ultrasonic sensor and the magnetometer sensor. Also, they suggested using the ultrasonic sensor for the purpose of classifying the type of vehicles and adjust the sensing period to be around 100ms in order to reduce the consumed energy. Arms et al. [5] reported that by forcing the system to sleep mode between reading samples, the consumed power will be reduced.

Hari [6] reported that the earth's surface magnetic field is disturbed by the metal composition of the vehicles. This perturbation can be detected by magnetic field sensors. The working principle of ultrasonic sensors is similar to radar, which calculates the required time for a signal to propagate and reflect back between the source of that signal and the target object. This period of time can be used in many ways

to determine: the speed of the object, the distance of the object, and also the wind speed [7].

The detection algorithm for ultrasonic sensor is simple and it depends on the measured distance between the vehicle and the sensor itself and also duration of detection [4]. We have to set period limit for ultrasonic sensor in order to differentiate between people moving around the parking lots and parked vehicles [8].

This paper presents a new solution to overcome the problems by designing a system that is able to guide the drivers toward the available lots and at the same time verify the legality of vehicles that parked in an authorized space.

2. Parking Guidance and Authentication System

There are three stages involved in the design of the parking guidance and authentication system.

1. Design of the detection and authentication module
   This module is responsible to detect the presence of vehicles and determine the legality of parking, then respond to the data requests from the data collector.
2. Design of the data-collector module
   This module is responsible to collect the data from all detection modules within each route and display the available parking lots in the information display. The module will also response to the data requests from the parking management software.
3. Programming the parking management software
   This software is responsible to monitor all connected detection modules within the whole parking area, configuring and analyzing the whole system.

The parking guidance and authentication system is composed of the previous three components: detection and authentication modules, the data-collector module, and the parking management software, as shown in Figure 1.

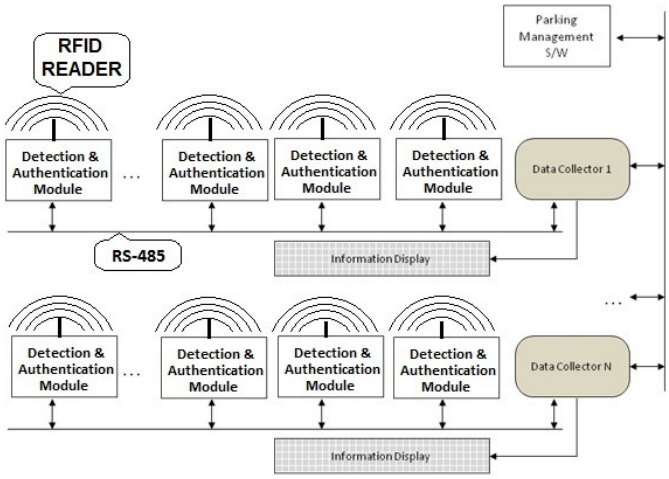


Figure 1. The overall system design

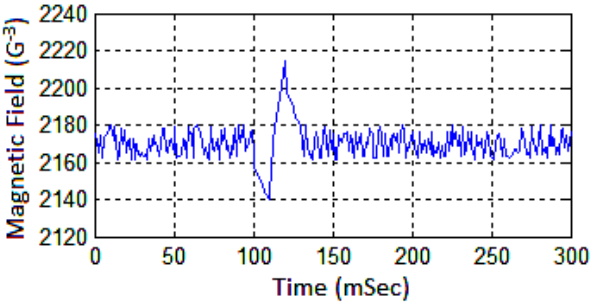
2.1 Vehicle detection module

There are two types of sensors used for detecting vehicles, which are ultrasonic sensor and magnetometer sensor. The detection algorithm for the ultrasonic sensor is used to differentiate between people and parked vehicles, which consists of two steps:

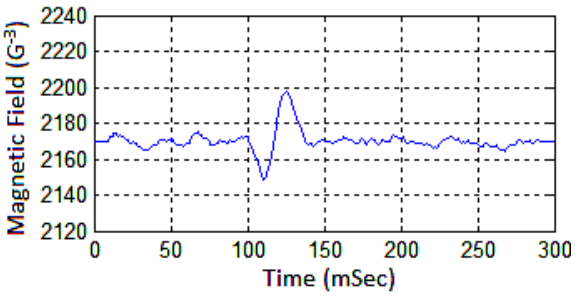
1. The reading distance is smaller than the threshold distance.
2. If the first condition is true for the 5 seconds threshold- time, a vehicle is detected.

The detection algorithm for the magnetometer sensor involved five steps as shown in Figure 2, in order to determine whether there is a vehicle or not.

1. Figure 2(a) shows the simulated raw data from the magnetometer (DATA). The signal in Figure 2(b) is the moving average order 10 of the simulated raw data i.e. MAVG.
2. e = (DATA-MAVG)^2. The signal e is shown in Figure 2(c).
3. f=Low pass filter (e). The signal f is shown in Figure 2(d).
4. Figure 2(e) shows the moving average order 10 of signal f.
5. Figure 2(f) shows the result of the detection signal. When the moving average is greater than the threshold value, a vehicle is detected (logic 1) or else it will be logic 0.



(a) Simulated magnetometer raw data



(b) MAVG = Moving average order 10 (raw data)

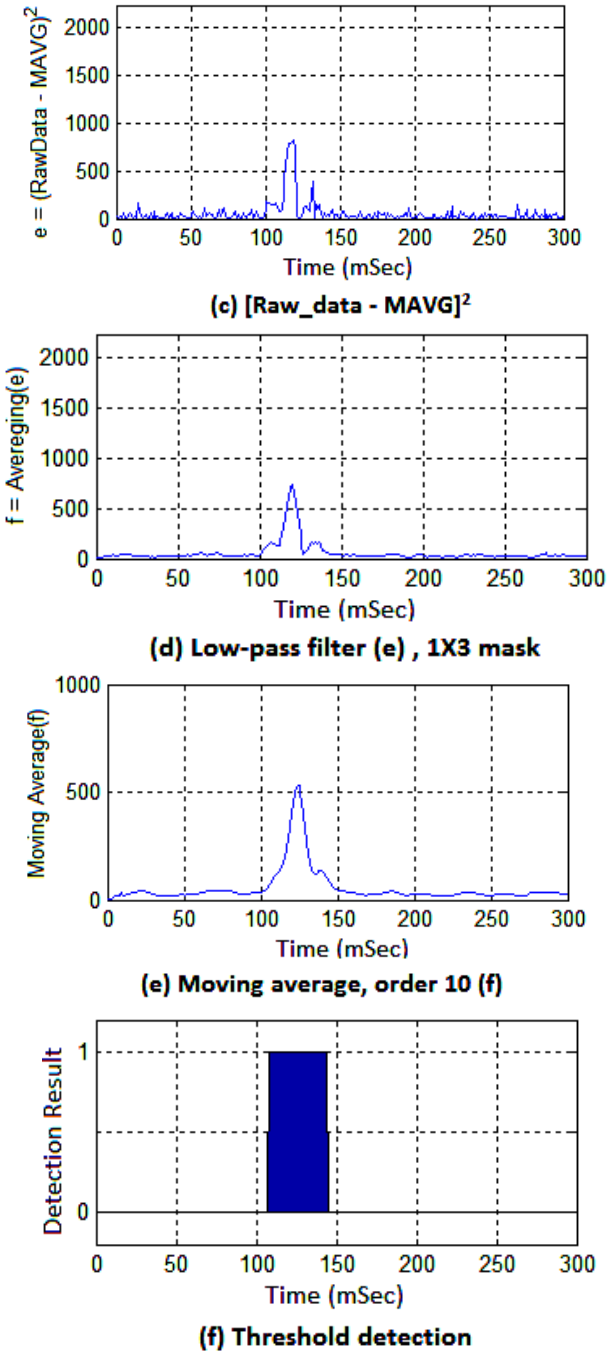


Figure 2. Magnetometer detection algorithm

2.2 Communication between the detection module, the data-collector module and the management software

The parking guidance system requires data transmission that supports long distances, multipoint network, and reliability. These requirements guided us toward the appropriate serial communication. According to the requirements, the RS-232 serial communication is not suitable for this application because it does not support the multipoint network. Moreover, the USB serial communication that supports the multipoint network is not suitable because it does not support long distance communication. Furthermore, we cannot use Ethernet for such application because the maximum distance per cable segment is 185 meters, which is not long enough.

The system adopted RS-485 because it meets the system data transmission requirements. This type of serial communication supports long distances up to 1200 meters (4000 feet) and it also supports the multipoint topology networks.

3. System Design

The parking guidance and authentication system guide drivers toward available lots and authenticate parked vehicles. The system is capable to do the following tasks:

1. Guiding the vehicle drivers toward the available parking lots by showing the available number of parking lots and the direction toward that section of parking space.
2. Authenticating each vehicle that occupied parking lots specified only for authorized people. And determining either this car is authorized to park here or not.
3. Monitoring the whole parking space via the management software, which is able to show the available parking lots, full-authorized parking lots, and full-not authorized parking lots.

3.1 Detection and authorization unit

The detection module should be able to detect the presence of vehicles as well as to determine whether these vehicles are authorized for parking or not. Therefore, this unit consists of a detection sensor and an ID verification module. An ultrasonic sensor is used as the detection module and a nrf24l01 transceiver module as the ID verification module as shown in Figure 3.

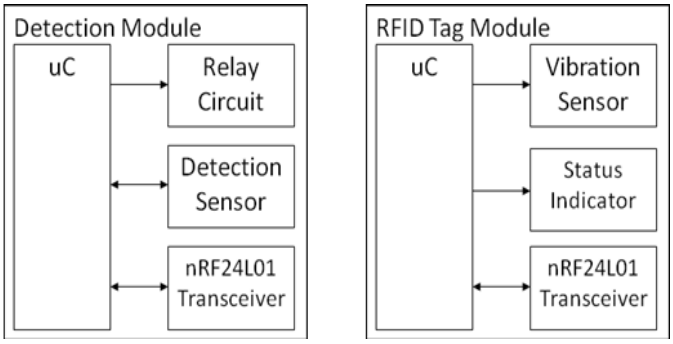


Figure 3. Detection and authorization unit

The data collector is the most important part of this system because it is responsible for guiding the drivers toward the available lots. The presence of vehicles can be determined simply by setting up a threshold value for the measured distance. The ID verification starts immediately after the detection signal.

The ID verification can be done by using two modules of nRF24L01 transceivers i.e. Tag module and Tag reader module. Each nRF24L01 transceiver has a Built-in hardware error detection (CRC) and address control for multipoint

communication [9]. The process of ID verification passes through the following steps and the process is shown in Figure 4:

1. All tags must be preconfigured to be operating in receiving mode and all tag readers should be in transferring mode. And every tag must have a unique address ID.
2. The tag reader will send any data to the address ID "Tag ID" of authorized vehicle after the detection signal.
3. The tag module will assemble and transmit the acknowledgment packet automatically by using Enhanced ShockBurstTM .
4. If the tag reader gets an ACK packet, that means the vehicle is authorized, otherwise it is unauthorized.

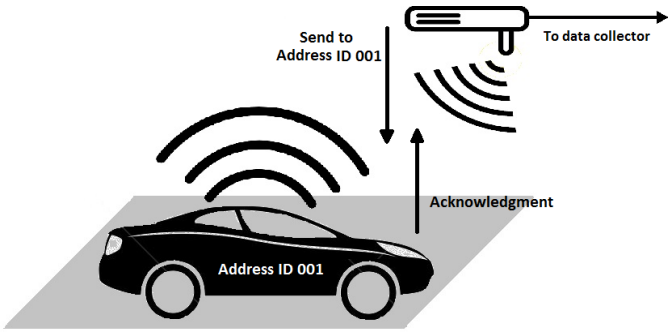


Figure 4. Authorization process

In order to avoid air data collision, an auto retransmitting feature is used. If there is no acknowledgment, the detection module will send another packet for several times within different periods of time automatically. If there is still no acknowledgment, it means that there is an unauthorized vehicle. In the tag side, the nRF24L01 will check the address and send the acknowledgment automatically, and it will be switched off if the vehicle starts to move. Because all tags are supposed to operat by an external battery, a led indicator is used to indicate the status of the battery.

3.2 Data collector unit

The data collector is the most important part of the system because it is responsible for guiding the drivers toward the available lots by using text scrolling display, which is a compound of 8x8 LED matrices.

In order to derive such 8x8 matrices, we used the MAX7219 IC driver that has the ability to connect many drivers in a cascade way in order to derive many led matrices with only one SPI peripheral port and one chip select line for the first LOAD pin as shown in Figure 5.

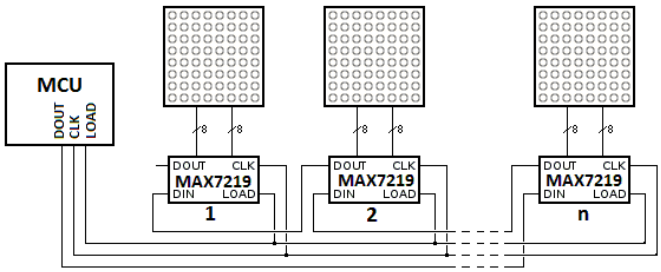


Figure 5. MAX7219 Cascade connection

As mentioned before, RS-485 is used because it meets the requirements. This type of serial communication supports long distances up to 1200 meters (4000 feet). Moreover, it supports the multipoint topology network as shown in Figure 6.

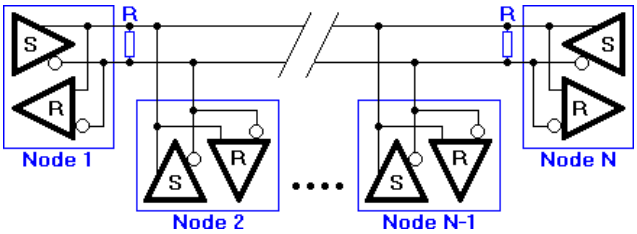


Figure 6. RS-485 Network topology

There are many types of IC drivers for the RS-485. They differ in the maximum allowed nodes, maximum data rate speed for specific distances, modes of operation either full-duplex or half-duplex, and other specifications. An interconnection protocol was developed in order to increase the reliability of the communication. According to this interconnection protocol, there are three types of commands:

1. Request Information Command (i.e. request status of
   detection module).
   Syntax: <*><Address_4bytes><Property>.
2. Edit Information Command (i.e. edit the address ID).
   Syntax: <*>< Address_4bytes ><Property><New Value>
3. Function Command (i.e. Calibration function).
   Syntax: <*><Address_4bytes><Function ID>.

3.3 Management software unit

This unit is used for monitoring, configuring, and analyzing the whole network of parking guidance and authentication system. Figure 7 shows the display of the parking management software.

Figure 7. Parking management software

According to the parking management software, the whole possible situations for the parking lots are:

1. Empty parking lot.
2. Full authorized.
3. Full unauthorized.
4. Full Long-Time: the parking lot is occupied by an authorized vehicle for a long time, longer than the predetermined and configurable period.
5. Not-Connected: the detection module is disconnected or does not respond to the data collector.
6. Initialization: it is just switched ON and the detection module is not ready yet.

Based on the results of our experiments, the authentication process can be done automatically by getting the advantages of the nRF24L01 transceivers. By adding this new ID verification feature to the parking guidance systems, the designing and managing of parking lots facilities become easier.

4. Conclusions

The developed smart parking guidance and authentication system has successfully performed the detection of available parking lots and verified any authorized vehicles. Further work needs to be done on parking management software in order to make it accessible remotely and suitable for more applications.

5. Acknowledgement

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